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Timing bait applications for control of imported fire ants (Hymenoptera: Formicidae) in Mississippi: Efficacy and effects on non-target ants*

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Abstract

An experiment was conducted to assess the efficacy of mid-day (11:00–13:00 h) and late evening (18:00–20:00 h) broadcast bait (Seige Pro®, 0.73% hydramethylnon) applications against black and hybrid imported fire ants (*Solenopsis richteri* Forel and *S. richteri* × *invicta*, respectively) and their impact on native ant species. It was hypothesized that evening bait applications would have less impact on native ant species that slow or cease foraging at night relative to mid-day applications. Bait was applied to a series of plots in northeastern Mississippi, USA, in summer of 2002 and 2003. Population densities and foraging activity of imported fire ants and native ants were compared between treated and control plots. Population density and foraging activity of imported fire ants were equally suppressed in plots receiving mid-day and evening broadcast bait applications. Population density of *Monomorium minimum* (Buckley), the little black ant, approached zero in treated plots during 2003 but remained relatively high in untreated control plots. Species richness declined in treated plots with no difference between mid-day and evening bait application. These data indicate that evening bait application offers no advantage over mid-day application in terms of preserving some native ant species.

Keywords: *Bait, fire ants, non-target effects, foraging*

1. Introduction

Black and red imported fire ants (*Solenopsis richteri* Forel and *S. invicta* Buren) were accidentally introduced into the southeastern USA from South America around 1918 and the 1930s, respectively (Lofgren 1986). Their large, aggressive colonies, high population density, stinging behavior, and unsightly mounds make them serious pests of human health, agriculture, and recreational activities. Some aspects of the history and impact of imported fire ants are reviewed by Vinson (1997). Their economic impacts in terms of insecticide costs, damage to equipment, and medical expenses have been well documented in urban and agricultural areas (Lard et al. 2002). Anaphylaxis can result from stings in at least 1% of cases (deShazo et al. 1990, 1999; deShazo and Williams 1995).

Black imported fire ants in the USA are currently restricted to several counties in northeastern Mississippi and northwestern Alabama (Shoemaker et al. 1994) as well as a few counties in south-central Tennessee. Red imported fire ants infest an area from central Texas to the Atlantic coast, with additional infestations in California and New Mexico. A broad band of hybridization (*S. richteri* × *invicta*) exists through central Mississippi, Alabama, and into Georgia (about 130 000 km^2) (Shoemaker et al. 1994). Red imported fire ants have recently been found in several sites throughout the West Indies (Davis et al. 2001) and were introduced into Australia in the late 1990s (McCubbin and Weiner 2002). Imported fire ants are a potential threat to tropical and temperate areas throughout the world (Morrison et al. 2004), making these insects an international concern.

While imported fire ants are capable of rapidly re-colonizing treated areas through mating flights and colony migration, several effective short-term control measures have been developed, including residual contact insecticides and granular or liquid baits (reviewed by Willams 1983; and Hays 1988). Some non-chemical control measures have been shown to be effective, such as drenching colonies with hot water (Tschinkel and Howard 1980). Cold-press citrus peel extract ('orange oil') can be effectively used as an organic alternative to conventional insecticides for drenching colonies (Vogt et al.

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2002). Unfortunately, these methods are not species-specific, nor do they provide long-term control of imported fire ants over large areas. One common active ingredient in baits for fire ant control (hydramethylnon) is also effective against other myrmicine ants (Zakharov and Thompson 1998). Broadcast application of contact insecticides has the potential to negatively affect numerous ground-dwelling arthropods, including non-target ant species.

Potential founder queens of imported fire ants are frequently preyed upon by other ant species (Whitcomb et al. 1973; Nickerson et al. 1975; Nichols and Sites 1991). Additionally, some common ant species such as the little black ant, *Monomorium minimum* (Buckley), are able to compete directly with imported fire ants at food sources (e.g., Vogt et al. 2004). The thief ant, *Solenopsis molesta* (Say), preys upon eggs and immatures of other ant species including red and black imported fire ants (O'Neal 1974). Thus, preservation of native ants in areas infested with imported fire ants may extend the life of insecticidal treatments by slowing reinfestation if a treatment differential favouring the beneficial species can be realized.

An initial study examining temporal foraging activity of imported fire ants and native ants at sites in northeastern Mississippi demonstrated clear differences in optimal foraging times between ant species (Vogt et al. 2004). *Solenopsis molesta* foraging activity peaked from 15:00 to 18:00 h and declined sharply thereafter. *Tapinoma sessile* (Say) foragers were not collected between 24:00 and 16:00 h in our study, though they may forage at night provided temperatures are favorable (Barbani L 2003, personal communication). Imported fire ants foraged at all times, with a slight decline from 12:00 to 15:00 h. Foraging activity of *M. minimum* peaked at mid-day, and declined to 0 between 21:00 and 06:00 h. A previous study in Texas concluded that *M. minimum* is a daytime forager (Claborn and Phillips 1986). Temperature also drives ant foraging activity; *M. minimum* and *S. molesta* tend to recruit at relatively high soil temperatures, up to 39–40°C in the case of *M. minimum* (Adams and Traniello 1981) and up to 36°C or more in the case of *S. molesta* (Vogt, unpublished data). Optimal soil temperature for foraging in *S. invicta* is about 28–29°C (Porter and Tschinkel 1987; Vogt et al. 2003) and is similar for *S. richteri* and *S. richteri* × *invicta* (Vogt et al. 2004).

Differences in foraging activity between ant species with respect to time and temperature led us to hypothesize that mid-day bait applications would have greater potential to negatively affect non-target ant species attracted to the bait when compared with late evening bait applications. Hence, we conducted an experiment to test this hypothesis in areas of northeastern Mississippi where native ant fauna and foraging activity were previously characterized.

2. Materials and methods

2.1. Study area and plot description

Study sites were located in Clay and Webster Counties, Mississippi, USA. These areas have mixed local populations of black and hybrid imported fire ants (Streett et al. 2002) (collectively considered as imported fire ants for the purposes of this study). Blocks ($n = 4$) were established along the Natchez Trace Parkway right-of-way (US Department of the Interior, National Park Service) (Trace site) with the southernmost at about 33°33(49(N, 89°08(01(W and the northernmost at about 33°47(08(N, 89°00(44(W. These areas were characterized by mixed forbs and grasses (primarily Bermudagrass, *Cynodon* sp.) and remained relatively undisturbed with the exception of occasional (1–2 times per year) mowing. Another series of blocks ($n = 4$) was established in a grazed pasture (about 33°16(39(N, 88°32(44(W) (Pasture site) consisting of fescue (*Festuca* sp.) with some Bermudagrass and patches of bare soil.

Each block consisted of three plots ranging in size from about 1.5 to 3 ha. Plot outlines were created using DGPS (differential global positioning system) receivers and SoloField® (Tripod Data Systems, Corvallis, OR, US) software. Each plot within a block was randomly assigned one of three treatments: (1) a mid-day bait application (bait applied between 11:00 and 13:00 h), (2) an evening bait application (bait applied between 18:00 and 20:00 h), or (3) an untreated control.

2.2. Bait application

Fire ant bait (Seige Pro®, 0.73% hydramethylnon, BASF Corporation, Research Triange Park, NC, USA) was applied using a Herd® GT-77 broadcaster mounted on the back of a Kawasaki Mule™ utility vehicle. The broadcaster was equipped with a restrictor plate supplied by Herd and designed to block all but one hole below the agitator, making it possible to calibrate the spreader to the very low application rate (about 1.68 kg ha^{-1}) required for most fire ant baits. Application rate was calculated based on a 7.3-m swath width and a spreader speed of 6.4 km h^{-1}. The spreader was calibrated by making a preliminary timed application in an area outside of the study sites with a known amount of bait in the hopper. To achieve even bait application and prevent overlapping swaths, two teams of two individuals, equipped with conspicuous flags and a 3.65-m rope and stationed on opposite sides of a plot, guided the applicator for each swath. Bait applications were made in July 2002 (Trace), August 2002 (Pasture), and May 2003 (Trace and Pasture).

2.3. Population sampling

Ant population sampling took place about 2 weeks before treatment and at intervals of 2–4 weeks after treatment, weather permitting. Fire ant nest density was estimated by establishing three sampling points within each plot and counting and measuring (L, W, H) each fire ant mound encountered within a 0.1-ha circular sub-plot centered on each sampling point. Mound activity was determined by probing each mound and looking for emergence of disturbed workers. Sampling points were located such that circular plot edges were at least several meters from plot boundaries. Fire ant density was expressed as the total area (m^2) within each 0.1-ha sub-plot occupied by active mounds, using mound area calculated as an ellipse:

$$\text{Area} = \pi \times a \times b$$

where a is the semi-major axis and b is the semi-minor axis.

Native ant species richness and density were estimated with pitfall traps. On each sampling date, four pitfall traps (polypropylene snap-cap vials, 2.54 cm I.D., about 7 cm deep) were placed within each circular sub-plot by drilling holes in the soil with a 2.54-cm auger bit and snugly inserting each vial so that its opening was flush with the soil surface. Each pitfall trap contained about 15 ml of propylene glycol. Pitfall traps were left in the field for 48 h, then capped and brought back into the laboratory for sorting.

Foraging ants were captured in baited vials on each sampling date to look for possible changes in resource dominance and relative foraging activity following bait treatments. Ten 12 × 75-mm disposable glass vials baited with small (about 0.5 cm^3) pieces of hotdog (Bryan® Meat Wieners (9.6% protein, 15% fat, 3% sugar), Bryan Foods, West Point, MS, USA) were placed on the soil surface within each circular sub-plot, left for 30 min, then quickly collected, plugged with cotton, and returned to the laboratory for species identification and sorting (similar to Vogt et al. 2004). Temperature (soil and air) and general weather conditions were noted on all sampling dates. Sampling took place between 10:00 and 15:00 h.

2.4. Statistical analysis

The experimental design for these experiments was a randomized complete block replicated 4 times, with sub-sampling; we considered years and sites separately in our analyses. Data were subjected to ANCOVA using Proc Mixed in SAS (Littell et al. 1996) to determine effects of time, treatment, and their interaction on the various measures of ant diversity and abundance at each site. For imported fire ant mound counts, the initial model included the fixed effects of treatment, time, and the treatment × time interaction; the model was reduced based upon examination of F-statistics. Random effects included plot, plot × treatment, and sub-plot within plot and treatment. Treatment effects were detected using differences of least squares means. Bait catch (number of individuals of each species per vial) was analyzed similarly, but an additional random term was added to account for variation by baited vial within circle, plot, and treatment. Pitfall traps yielded data on species richness as well as relative quantitative data on the various species collected; quantitative data were analyzed as described above for bait catch. Qualitative data (species richness) were analyzed using a comparative index (Zakharov and Thompson 1998). Sites were combined for analysis. The following index was calculated for each time-treatment combination:

$$l_i = \log_{10}(N_{i,t}/N_{i,c}) \qquad (1)$$

where l_i is the diversity index for the ith time–treatment combination, $N_{i,t}$ is the number of species from each treated sub-plot for time–treatment combination i, t refers to mid-day or evening treatment, and c refers to the untreated control sub-plot. N_t was then regressed against N_c for each sampling period. Larger index values indicated greater species diversity when compared to untreated controls, smaller values indicated less species diversity. Regression statistics were compared to determine whether changes in species richness were different between mid-day and evening treatments.

3. Results and discussion

3.1. Efficacy against imported fire ants

Sampling (baited vials and pitfall traps) was interrupted numerous times by rain in 2002 after 4 and 8 weeks following treatment at the Pasture and Trace sites, respectively, resulting in missing data. Mean area occupied by imported fire ant mounds in sub-plots for each site-year combination are illustrated in Figure 1. At the Pasture site in 2002, fixed effects of treatment and time influenced the total area of sub-plots occupied by active fire ant mounds, with treatment effects increasing over time (Figure 1A). Overall treatment effects indicated significant reduction in fire ant mound area relative to the control for both mid-day and evening plots ($t = 2.39$, df = 30, $P = 0.0234$ and $t = 2.57$, df = 30, $P = 0.0154$, respectively) but no significant difference between mid-day and evening plots ($P = 0.8590$). In 2003, mean area occupied by active mounds was still lower in evening and mid-day treatment plots than control plots ($t = 5.84$, df = 9, $P = 0.0002$, and $t = 5.32$, df = 8, $P = 0.0006$, respectively) (Figure 1B). Again, there was no difference between mid-day and evening plots ($P = 0.5598$). Data were more variable at the Trace site, where treatment alone did not explain a significant proportion of the variation in total active mound area in 2002, but time effects indicated a relatively rapid treatment-induced drop in popula-

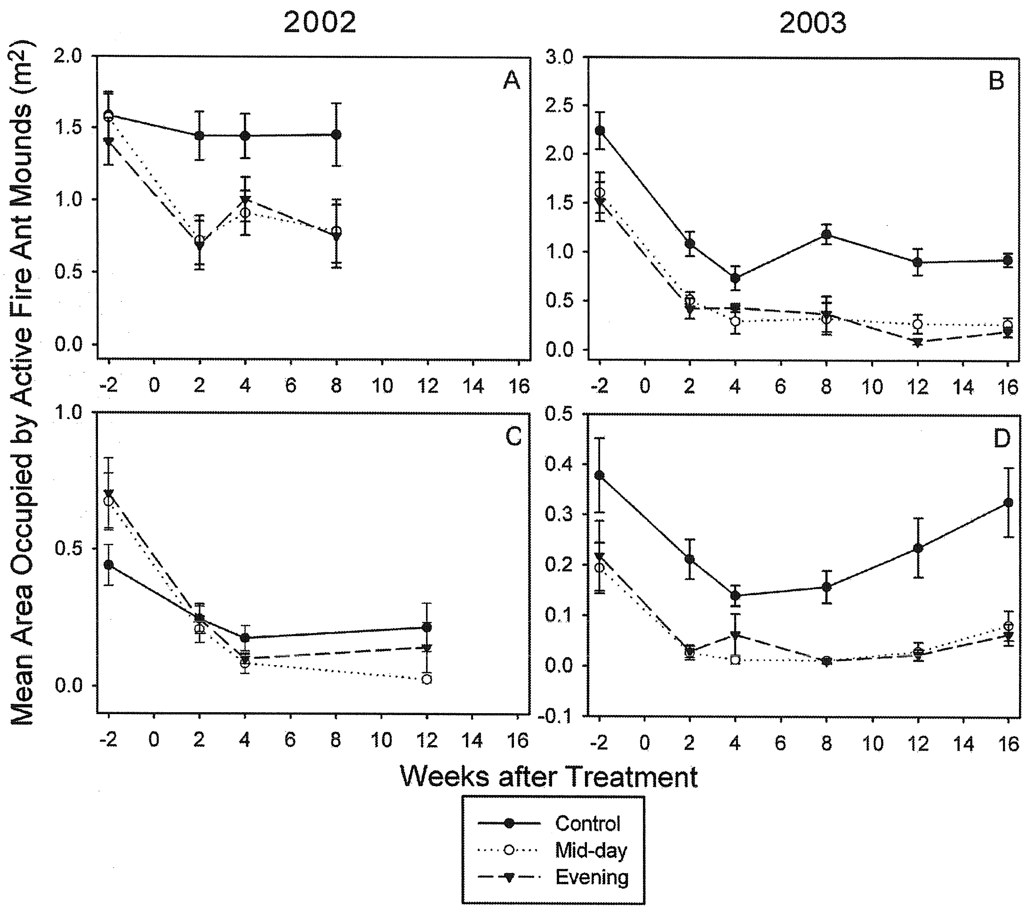

Figure 1. Mean area occupied by active imported fire ant (*Solenopsis richteri* and *S. richteri* × *invicta*) mounds in experimental plots following mid-day, evening, and no bait application in 2002 and 2003 at Pasture site (A and B, respectively) and Trace site (C and D, respectively).

tion densities within all plots (Figure 1C). In 2003 at the Trace site, treatment and time explained significant proportions of the variation in total mound area (Figure 1D). Total mound area was similar between evening and mid-day plots ($P = 0.8801$) but lower in evening and mid-day plots than in controls ($t = 4.29$, df = 6, $P = 0.0050$ and $t = 4.46$, df = 6, $P = 0.0042$, respectively). *F*-statistics for the reduced models are presented in Table I. In general, after bait application, treated plots had fewer and smaller ant colonies than controls. No significant differences were observed between mid-day treatment plots and evening treatment plots for any sampling period.

Treatment, time, and treatment × time all had significant effects on imported fire ant foraging activity (expressed as number of ants per baited vial). *F*-Statistics are presented in Table II. Foraging activity was suppressed in treated plots within 2 weeks of bait application; data are presented in Figure 2. Interestingly, forager activity exhibited a much more pronounced treatment effect than area occupied by active mounds, particularly when compared to the Trace site in 2002. Each sampling method has advantages and disadvantages; for example, with regard to mound counts and measurements, dense vegetation or poor condition of mounds due to dry conditions can cause observers to overlook mounds. With regard to capturing foragers, temperature influences foraging rates and trap catch (e.g., Porter and Tschinkel 1987; Vogt et al. 2003). In this study, mean soil temperature (2 cm deep) during forager collections varied across sampling times, but not between treatments, so forager collections should yield a true estimate of relative activity between treatments on each date. The lowest temperature during sampling was 19.7 ± 0.05°C (mean ± SE; Pasture site, 2001, 4 weeks) and the highest was 32.8 ± 0.33°C (Pasture site, 2003, 8 weeks). The overall mean soil temperature during sampling was 29.9 ± 0.29°C, very similar to optimal foraging temperature of the red imported fire ant, *S. invicta* (Porter and Tschinkel 1987; Vogt et al. 2003).

3.2. *Effects on other ant species*

Species captured in baited vials and pitfalls in this study are listed in Table III. Imported fire ants were by far the most abundant ants, comprising more than

Table I. *F*-Statistics for mean area occupied by active *S. richteri* and *S. richteri* × *invicta* mounds over time in plots receiving mid-day, evening, and no bait application.

Site (year)	Effect*	df	*F*	*P*
Pasture (2002)	Treatment	2, 30	4.11	0.0264
	Time	3, 99	21.00	< 0.0001
	Treatment × Time	6, 99	3.24	0.0060
Pasture (2003)	Treatment	2, 9	21.17	0.0004
	Time	5, 147	68.76	< 0.0001
Trace (2002)	Time	3, 76	48.89	< 0.0001
	Treatment × Time	8, 85	2.21	0.0347
Trace (2003)	Treatment	2, 6	12.80	0.0065
	Time	5, 158	14.64	< 0.0001

*Only significant effects are shown (Proc Mixed, $P < 0.05$). 'Treatment' = mid-day, evening, and no bait application, 'Time' = weeks after treatment.

Table II. *F*-Statistics for mean number of *S. richteri* and *S. richteri* × *invicta* foragers captured in hotdog-baited vials over time in plots receiving mid-day, evening, and no bait application.

Site (year)	Effect*	df	*F*	*P*
Pasture (2002)	Treatment	2, 31	4.09	0.0268
	Time	2, 702	366.92	< 0.0001
	Treatment × Time	4, 702	8.35	< 0.0001
Pasture (2003)	Treatment	2, 6	6.37	0.0327
	Time	5, 1574	50.20	< 0.0001
	Treatment × Time	10, 1576	11.52	< 0.0001
Trace (2002)	Treatment	2, 29	7.27	0.0027
	Time	2, 807	52.95	< 0.0001
	Treatment × Time	4, 708	16.50	< 0.0001
Trace (2003)	Treatment	2, 6	8.11	0.0197
	Time	4, 1420	49.86	< 0.0001
	Treatment × Time	8, 1420	19.26	< 0.0001

*' Treatment' = mid-day, evening, and no bait application, 'Time' = weeks after treatment.

86% of the total collected. Overall effects of bait treatments on ant populations at the sites can be expressed qualitatively as changes in species richness, measured using pitfall traps. We made the general assumption that heterogeneity in detectability of relatively abundant ant species would not pose difficulties for simple comparisons between treatments with a standard sampling protocol. Heterogeneity exists between likelihood of capture at baits versus pitfall traps for some species as indicated by the three species that were more abundant in pitfall traps than at baits compared with six species that were more abundant at baits (Table III). Additional species may have been present at the sites but not collected. The scope of inference for these data is therefore limited to those species readily collected using pitfall traps. Data were combined over sites and years to give a general idea of changes in species richness following insecticidal treatment. ANOVA indicated that species richness in control and treatment plots was statistically indistinguishable prior to treatment ($F = 1.7$, df = 2, 6, $P = 0.2577$) and averaged 2.92 ± 0.24. Only post-treatment data were included in the diversity index analysis. The diversity index ($\log_{10} N_t/N_c$) decreased with increasing species richness in control plots for both mid-day and evening treatments ($F = 32.3$, df = 1, 44, $P < 0.0001$ and $F = 36.0$, df = 1, 42, $P < 0.0001$, respectively) (Figure 3). These relationships shared common slope and intercept, indicating no significant difference in diversity index between plots receiving mid-day versus evening bait application; species richness was generally reduced in both treatments. Species richness in pitfall traps combined over plots ranged from 1 to 5 on any given sampling date.

Pitfall trap data were also used to describe ant populations quantitatively for analysis. To look for collective changes in population density of ant species other than *S. richteri* and *S. richteri* × *invicta*, the total number of native ants was tallied per pitfall trap, $\log_{10}$-transformed, and analyzed as described in Section 2.4. *F*-Statistics are summarized in Table IV, and data are presented graphically in Figure 4. At the Pasture site in 2002, time significantly influenced total native ant catch in pitfalls, with a decrease following bait application that varied with treatment. The following year, mid-day and evening treatment plots had significantly fewer native ants per pitfall trap than control plots on several dates (Proc Mixed; $P < 0.05$); at no time during sampling were there any significant differences between mid-day and evening treatment plots (Proc Mixed, $P > 0.05$) (Figure 4).

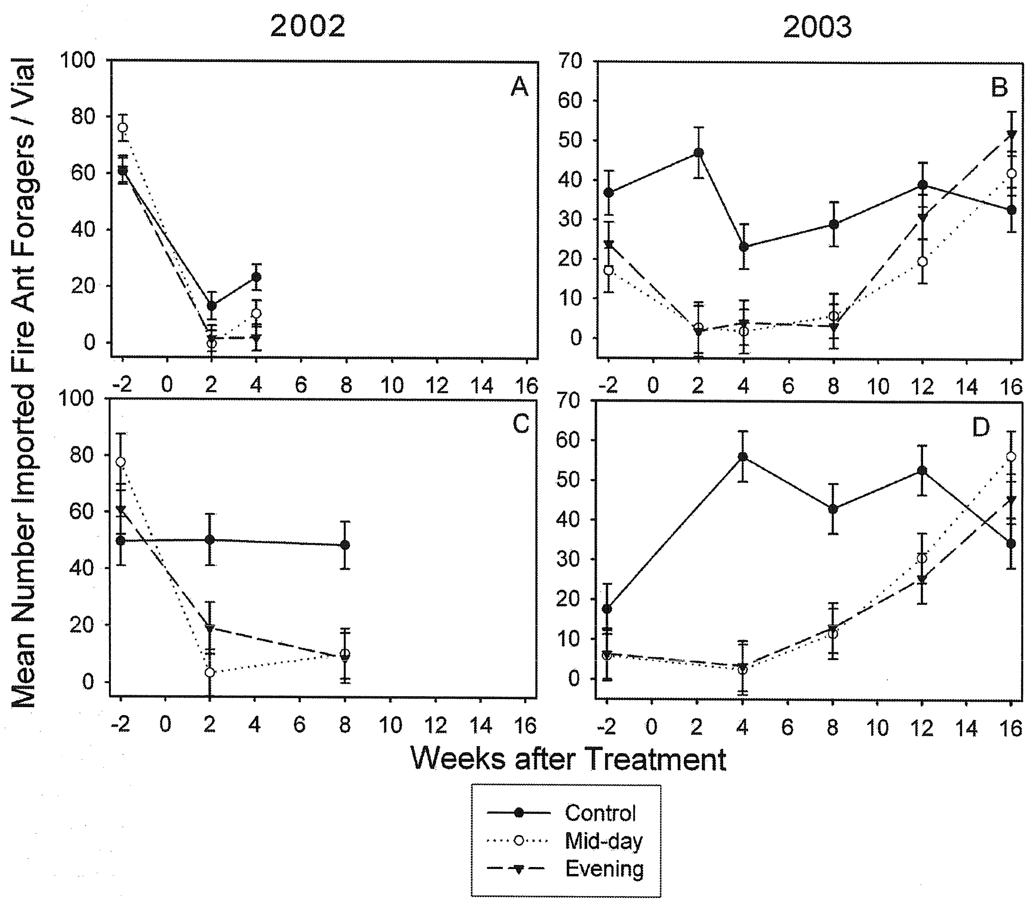

Figure 2. Mean number of foraging imported fire ants (*Solenopsis richteri* and *S. richteri* × *invicta*) captured in experimental plots following mid-day, evening, and no bait application in 2002 and 2003 at Pasture site (A and B, respectively) and Trace site (C and D, respectively).

Table III. Summary data on ant species collected in hotdog-baited vials and in pitfall traps in northern Mississippi (in order of abundance).

Species	Bait vials	Pitfalls	Total	Percent
Solenopsis richteri Forel and S. richteri × invicta	152 566	14 853	167 419	86.235
Monomorium minimum (Buckley)	23 482	874	24 356	12.544
Tapinoma sessile (Say)	855	78	933	0.481
Paratrechina vividula (Nylander)	200	241	441	0.226
Solenopsis molesta (Say)	313	156	469	0.241
Forelius pruinosus (Roger)	7	230	237	0.121
Pheidole tysoni Forel	142	32	174	0.090
Hypoponera opacior (Forel)	0	110	110	0.056
Strumigenys louisianae Roger	0	4	4	0.002
Total	177 565	16 578	194 143	100

The most abundant native ant present in pitfall traps was *M. minimum*. Trends in pitfall trap catch for this species were similar to trends in total native ants; *F*-statistics are presented in Table V, and data are illustrated in Figure 5. While other ant species were present in pitfall traps, uneven distribution among plots prior to treatment, low numbers, and sporadic collections made additional analyses impracticable.

With the exception of *M. minimum*, native ants were not distributed evenly throughout the sites and were collected in low numbers using baited vials. Foraging activity of *M. minimum* varied with time, an effect that was influenced by treatment (Figure 6); *F*-statistics are presented in Table VI. The overall treatment effect bordered on significance for the Pasture site in 2003 (Proc Mixed, $P = 0.0544$). *Monimorium minimum* foragers collect a wide variety of foods, and were observed recruiting to bait particles in the field following mid-day treatments (JTV, personal observations). *Tapinoma sessile* (Say) appeared in relatively large numbers in baited vials (Table III), but only at the

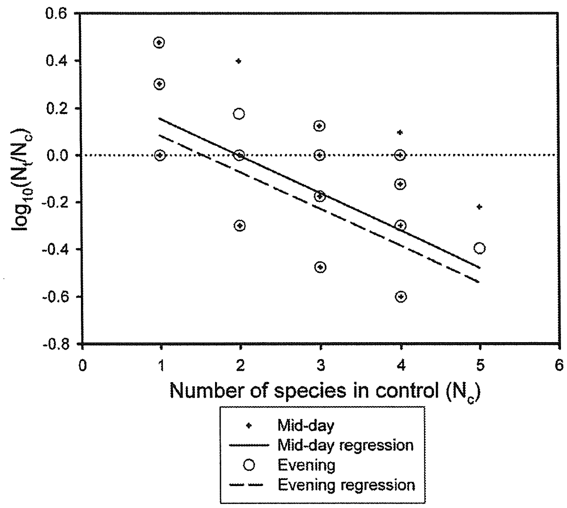

Figure 3. Comparative index ($\log_{10}$ ratio of ant species collected in plots receiving mid-day (solid line) and evening (broken line) insecticidal bait applications (N_t) to that in an untreated control plot (N_c)) for ants sampled using pitfall traps in northeastern Mississippi, USA. Dotted line indicates where $N_t = N_c$; positive values mean $N_t > N_c$, negative values mean $N_t < N_c$. The lines share common slope and intercept [$y = 0.28$ (± 0.06) $-$ 0.16 (± 0.02)x].

Trace site in 2002. Neither time nor treatment had a significant effect on *T. sessile* foraging as measured using baited vials (Proc Mixed, $P > 0.05$). *Paratrechina vividula* (Nylander) foragers were captured on all sampling dates in control plots at the Trace site in 2002, but were not captured in mid-day treatment plots following bait application and were only captured in evening treatment plots on one occasion, 12 weeks after bait application. Pitfall trap collections yielded *P. vividula* specimens for the majority of sampling date-treatment combinations at the Trace site in both years of the study, but in low numbers with no detectable trends. *Solenopsis molesta* (Say) collections in baited vials fluctuated over time in control and treatment plots, with no detectable trends.

4. Conclusion

Both mid-day and evening bait applications appeared to dramatically reduce population density of *M. minimum* in treated plots, and had the overall effect of reducing ant diversity. There were no

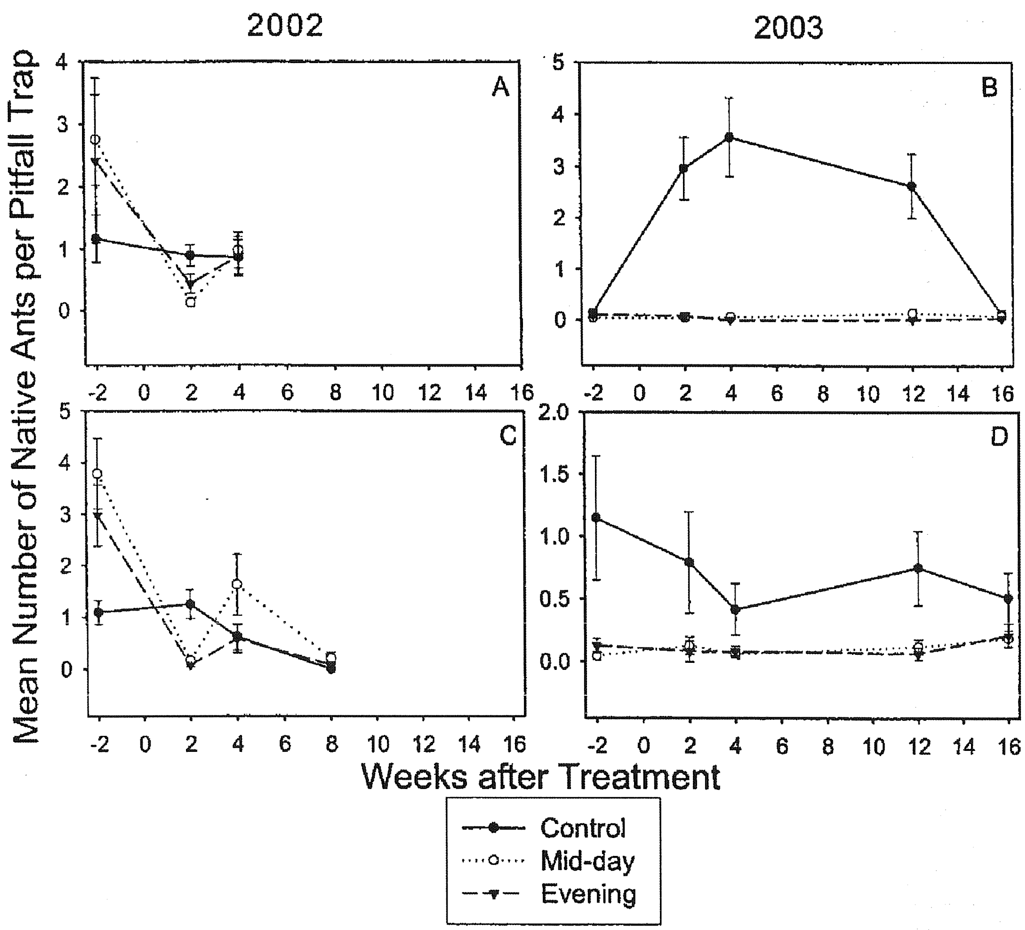

Figure 4. Mean number of native ants (various species) captured in pitfall traps in experimental plots following mid-day, evening, and no bait application in 2002 and 2003 at Pasture site (A and B, respectively) and Trace site (C and D, respectively).

Table IV. *F*-Statistics for $\log_{10}$-transformed ant catch (several species, excluding *S. richteri* and *S. richteri* × *invicta)* in pitfall traps in plots receiving mid-day, evening, and no bait application.

Site (year)	Effect*	df	*F*	*P*
Pasture (2002)	Time	2, 376	13.16	< 0.0001
	Treatment × Time	6, 31	3.82	0.0057
Pasture (2003)	Treatment	2, 6	6.46	0.0319
	Time	4, 669	18.55	< 0.0001
	Treatment × Time	8, 669	20.72	< 0.0001
Trace (2002)	Time	3, 386	48.84	< 0.0001
	Treatment × Time	8, 184	6011	< 0.0001
Trace (2003)	–	–	–	–

*Only significant effects are shown (Proc Mixed, $P < 0.05$). 'Treatment' = mid-day, evening, and no bait application, 'Time' = weeks after treatment.

Table V. *F*-Statistics for $\log_{10}$-transformed mean number of *M. minimum* captured in pitfall traps over time in plots receiving mid-day, evening, and no bait application.

Site (year)	Effect*	df	*F*	*P*
Pasture (2002)	Time	2, 380	11.94	< 0.0001
Pasture (2003)	Treatment	2, 6	6.01	0.0370
	Time	4, 666	24.15	< 0.0001
	Treatment × Time	8, 666	23.01	< 0.0001
Trace (2002)	Time	3, 378	16.89	< 0.0001
	Treatment × Time	8, 46	4.56	0.0004
Trace (2003)	–	–	–	–

*Only significant effects are shown (Proc Mixed, $P < 0.05$). 'Treatment' = mid-day, evening, and no bait application, 'Time' = weeks after treatment.

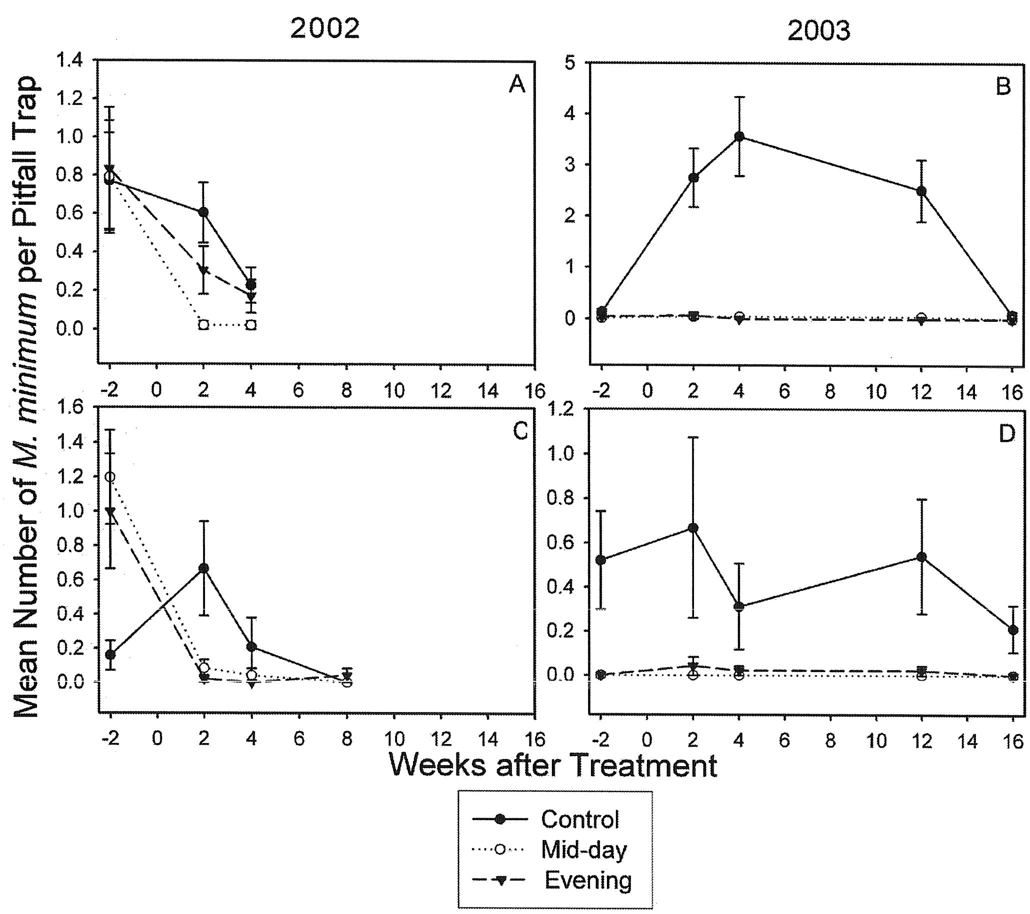

Figure 5. Mean number of *Monomorium minimum* captured in pitfall traps in experimental plots following mid-day, evening, and no bait application in 2002 and 2003 at Pasture site (A and B, respectively) and Trace site (C and D, respectively).

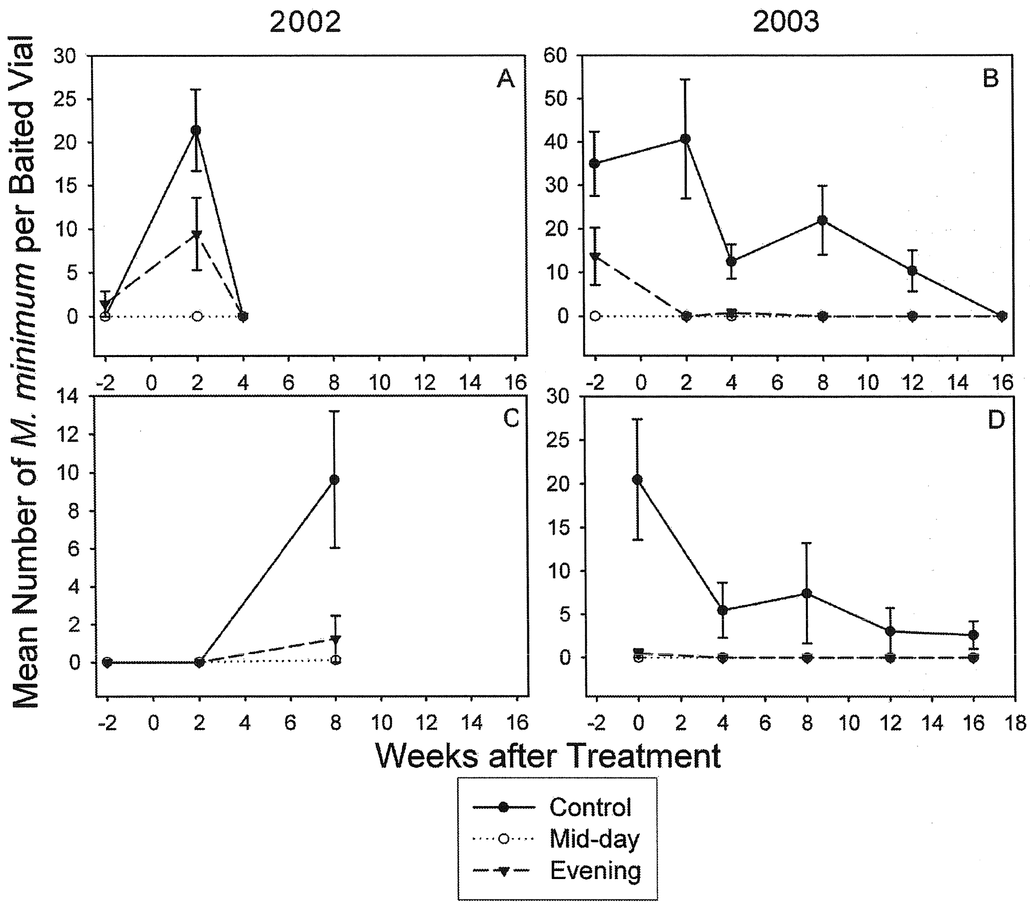

Figure 6. Mean number of *Monomorium minimum* captured in hotdog-baited vials in experimental plots following mid-day, evening, and no bait application in 2002 and 2003 at Pasture site (A and B, respectively) and Trace site (C and D, respectively).

Table VI. *F*-Statistics for mean number of *M. minimum* captured in baited vials over time in plots receiving mid-day, evening, and no bait application.

Site (year)	Effect*	df	*F*	*P*
Pasture (2002)	Time	2, 1024	23.35	< 0.0001
	Treatment × Time	6, 33	6.30	0.0002
Pasture (2003)	Time	5, 1528	8.13	< 0.0001
	Treatment × Time	12, 111	4.50	< 0.0001
Trace (2002)	Time	2, 822	8.44	0.0002
	Treatment × Time	6, 30	29.50	0.0035
Trace (2003)	Time	4, 1422	3.08	0.0153
	Treatment × Time	10, 80	2.65	0.0077

*Only significant effects are shown (Proc Mixed, $P < 0.05$). 'Treatment' = mid-day, evening, and no bait application, 'Time' = weeks after treatment.

detectable trends indicating differences between mid-day and evening bait applications. Some ant species in the subfamily Dolichoderinae appear to benefit from bait treatments targeted toward imported fire ants (Zakharov and Thompson 1998); however, no treatment effects were detected for either *T. sessile* or *F. pruinosus* in this study. Releasing treated areas from imported fire ant domination with repeated bait applications may allow other ant species to build up greater populations over time (e.g., Zakharov and Thompson 1998). The purpose of this study was to determine whether bait application during periods of reduced activity by some native ants would result in their preservation in the short term following application. Obviously, some native ants were able to retrieve enough bait to reduce their population densities in plots receiving mid-day and evening bait applications, and overall species richness was reduced in treated plots. The similarity between mid-day and evening treatments with regard to *M. minimum* is particularly interesting, since this species greatly reduces foraging activity at night (Vogt et al. 2004). Foraging *M. minimum* may have been active in low numbers during evening bait applications, or may have retrieved bait the following day. Imported fire ant population densities were reduced by both application times. While the two application times tested in this study were effective against imported fire ants, the evening bait application appeared to offer no advantage with regard to native ant preservation. Keeping in mind the limits of this study (only two application times, limited geographical scope), the broader hypothesis that broadcast bait applications can be timed to preserve native ants was neither proven nor rejected. Optimal foraging times of different species clearly differ (Claborne and Phillips 1986; Vogt et al. 2004), warranting further investigation. Future work might include additional application times and possibly different bait products.

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